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Newfoundland and Labrador Region

Canadian Science Advisory Secretariat
Science Advisory Report 2017/002

STOCK ASSESSMENT OF NAFO SUBDIVISION 3PS COD

Image: Gadus morhua.

Figure 1: Subdivision 3Ps management area and economic zone around the French islands of St. Pierre et Miquelon (SPM) (dashed line).

Context:

In the Northwest Atlantic, cod are distributed from Greenland to Cape Hatteras and are managed as 12 stocks. The Northwest Atlantic Fisheries Organization (NAFO) Subdivision 3Ps stock off southern Newfoundland extends from Cape St. Mary's to just west of Burgeo Bank, and over St. Pierre Bank and most of Green Bank (Fig. 1).

The distribution of 3Ps cod does not conform well to management boundaries and the stock is considered a complex mixture of inshore and offshore sub-components. These may include fish that move seasonally between adjacent areas as well as fish that migrate seasonally between inshore and offshore. The extent to which the different components contribute to the fisheries is not fully understood.

Female cod from this stock are generally maturing at younger ages in recent years. For example, about 50% of the females are mature by age 5 (~47 cm) in recent cohorts, compared to only about 10% at age 5 (~55 cm) among cohorts present in the 1970s-early 1980s.

Catches from this stock have supported an inshore fixed gear fishery for centuries and are of vital importance to the area. Fish are caught offshore by mobile and fixed gear, and inshore by fixed gear only. Spanish and other non-Canadian fleets heavily exploited the stock in the 1960s and early 1970s. French catches increased in the offshore throughout the 1980s. A moratorium on fishing initiated in August, 1993 ended in 1997 with a quota set at 10,000 t. Beginning in 2000, the management year was changed to begin on 1 April. The Total Allowable Catch (TAC) for the 2015/16 management year was set at 13,490 t. Under the terms of a 1994 Canada-France agreement, Canada holds 84.4% of the TAC, while the remainder (15.6%) is held by France (St. Pierre et Miquelon).

The present assessment is the result of a request for science advice from the Fisheries Management Branch (Newfoundland and Labrador [NL] Region). The main objectives were to evaluate the status of the stock and to provide scientific advice concerning conservation outcomes related to various fishery management options.

January 2017

Canada

Participants included Fisheries and Oceans Canada (DFO) scientists and fisheries managers, a scientist from the French Research Institute for Exploitation of the Sea (IFREMER; France), academia, fishing industry representatives from Canada, and a representative from the province of NL.

This Science Advisory Report is from the October 17-19, 2016 Assessment of NAFO Subdivision 3Ps Atlantic Cod. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- Although the stock is currently estimated to be in the Cautious Zone (18% above B_{lim}) as defined by the DFO Precautionary Approach (PA) Framework; the probability that the stock is in the critical zone is 0.22, which is a concern.
- There are further concerns that the current estimate of spawning stock biomass (SSB) could be biased as the model has overestimated SSB in recent years.
- The SSB has declined since 2012 and there are few older (ages 6+) fish in the population.
- The strong 2011 cohort is now of age to recruit to the fishery. The subsequent cohorts are lower but near the time-series average.
- Estimated total mortality has been increasing and the 2015 value is the time-series maximum. Over 2013-15, total mortality averaged 0.73 (52% per year). This is very high considering that landings have been about half of the TACs over this time period.
- Projection of the stock to 2019 was not conducted. If the current high mortality rate persists, it will result in a sharp decline in biomass in the coming years.
- Recent trends in mean size and weight-at-age, fish condition and age-at-maturity are at or near their lowest observed levels. This is consistent with broader ecosystem trends (e.g. warming temperatures, changes in community structure and cod diet composition) which also suggest some aspects of cod productivity may be impaired.
- Catches of approximately half the TAC generated from the Harvest Control Rule (HCR) in recent years have not promoted recovery of the stock toward the healthy zone. It was therefore not considered prudent to provide management advice based on the HCR.
- Given the downward trajectory of the stock in recent years, coupled with the current close proximity of the stock to the LRP, it is recommended that catch be reduced below recent levels.

INTRODUCTION

Oceanography and Ecosystem Overview

Oceanographic conditions in the 3Ps area are influenced by several factors including local atmospheric climate conditions, advection by the Labrador Current from the east and the warmer and saltier Gulf Stream waters from the south as well as the complex bottom topography in the region. Near bottom temperatures, while showing significant variability from one year to the next, have experienced a general warming trend for over two decades. In recent years, temperatures have decreased somewhat from a high in 2012 but increased again in 2016.

The overall biomass of the fish community in 3Ps has remained relatively stable since the mid-1990s, whereas the overall abundance has increased due mainly to an increase in small planktivorous (plankton-eating) fishes (e.g. sandlance). Atlantic Cod has historically been the

dominant piscivorous (fish-eating) species in 3Ps but since 2010 there has been a sharp rise in the biomass of Silver Hake (*Merluccius bilinearis*), typically considered a warmer-water species. The increase in Silver Hake biomass may be linked to the warming trend in this ecosystem.

Cod in 3Ps have a highly variable diet, with the dominant prey species changing over time (e.g. redfish in 1993-95, small pelagic fishes like capelin and sandlance in 1996-97). In 2013-16 the diet of smaller cod tended to be dominated by sandlance and crabs, with Snow Crab increasing in importance in the diet with cod size. The current invertebrate-dominated diet is likely of poorer quality than one based on fish. Preliminary diet data for Silver Hake in 3Ps suggest that this species is not in direct competition with cod for food.

These changes in species composition and cod diet are evidence that the structure of the ecosystem in 3Ps may be changing. Although the full impacts of these changes on cod are still unknown, they seem to imply that at least some aspects of cod productivity may be impaired.

History of the Fishery

The stock was heavily exploited in the 1960s and early 1970s by non-Canadian fleets, mainly from Spain, with catches peaking at 87,000 t in 1961 (Fig. 2).

After the extension of jurisdiction in 1977, landings increased to peak at almost 59,000 t in 1987 due to increased landings by France. Landings then decreased sharply to about 40,000 t during 1988-91 before decreasing further to 36,000 t in 1992.

A moratorium was imposed in August, 1993 after only 15,000 t had been landed. Although offshore landings fluctuated, the inshore fixed gear fishery reported landings around 20,000 t each year until the moratorium.

The fishery reopened in May, 1997 with a TAC of 10,000 t, increasing to 30,000 t by 1999. In 2000 the management year was changed to begin on 1 April. Total Allowable Catches and landings over the past decade are shown in Table 1 and are described in detail below. The TAC was set at 13,490 t for the 2015/16 management year and 13,043 t for the ongoing 2016/17 management year.

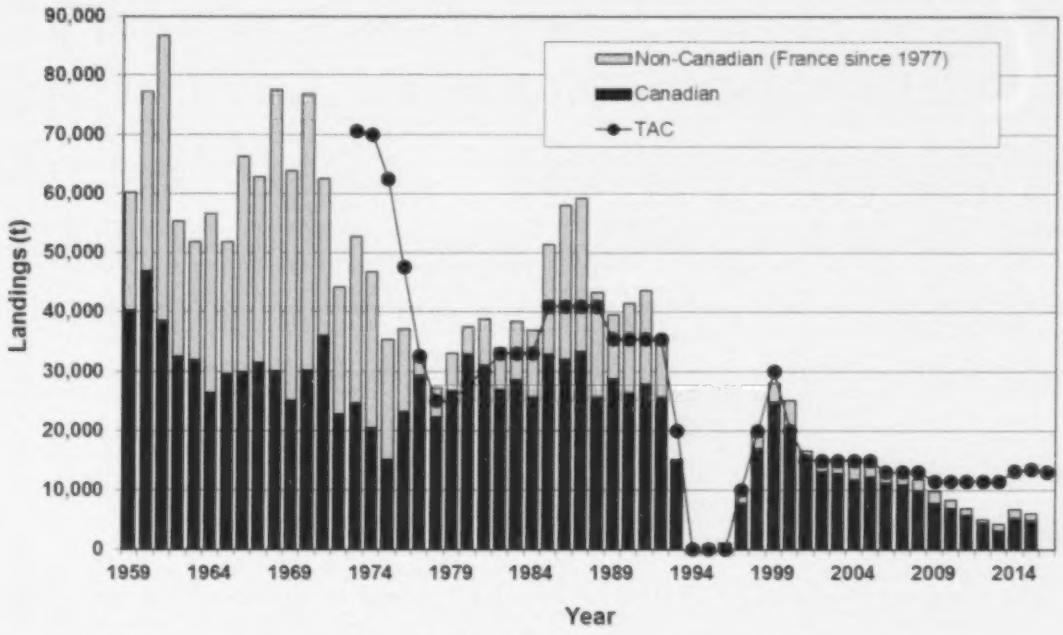

Figure 2: Reported annual landings and TACs (t) from 1959-2016. Values are based on calendar year from 1959-2000 and on management year (1 April-31 March) since then. Landings for 2016 (2016/17 season) are incomplete and not displayed.

Landings

Table 1: TAC and landings by management year (thousand metric tons).

Management Year	07-08	08-09	09-10	10-11	11-12	12-13	13-14	14-15[1]	15-16[1,2]	16-17[1,2]
TAC[3]	13.0	13.0	11.5	11.5	11.5	11.5	11.5	13.225	13.49	13.043
Canada	10.8	10.6	7.5	6.6	5.2	4.0	4.6	5.6	5.5	1.8
France	2.0	2.0	1.5	1.3	1.1	0.8	1.4	1.6	0.9	0.3
Totals	12.8	12.6	9.0	7.8	6.3	4.8	6.0	7.2	6.4	2.1

[1] Provisional.
[2] Approximate landings to September 29, 2016.
[3] TAC is shared between Canada (84.4%) and France (St. Pierre et Miquelon; 15.6%).

Reported combined landings by Canada and France have been substantially below the TAC since the 2009/10 season. During the 2015/16 season, approximately half (48%) of the 13,490 t TAC was landed. Prior to 2009/10, the TAC had been almost fully subscribed with the exception of the initial four years of TAC regulation. Industry participants have indicated multiple reasons contributing to the recent reduction in landings, including reduced cod availability and economic factors. Of the 6,427 t landed during the 2015/16 season, 5,522 t was taken by Canada (including 13 t from sentinel surveys), and 905 t was landed by France.

Provisional data (as of September 29, 2016) indicate landings during the ongoing 2016/17 management year were 2,088 t, of which 273 t was landed by France. Although incomplete, these landings to date are relatively low, and it is likely that much of the 2016/17 TAC of 13,043 t will not be caught.

During the 2015/16 season, approximately two-thirds of the total landings were taken by fixed gears (dominated by gillnet) with the remainder taken by the otter trawl fleet.

Species Biology

Stock structure and **migration patterns** of 3Ps cod are complex. Cod in 3Ps mix with adjacent stocks at the margins of the stock boundary. Some offshore components of the stock migrate seasonally to inshore areas, and there are inshore components that are shoreward of the spring DFO Research Vessel (RV) trawl survey area. These features add uncertainty to the assessment of stock status. However, since the moratorium, new information has been obtained from various sources, including tagging, acoustic telemetry, and the sentinel fishery. This information has provided a basis for several new measures to be put in place to reduce the potential impact of these factors (i.e., stock structure and migration patterns) on the assessment. Survey timing has been delayed until April (beginning in 1993) and winter area closures have been imposed to reduce the potential for migrant non-3Ps cod being included in surveys and commercial catches. The area surveyed during the spring DFO RV trawl survey has also been extended shoreward and by 1997 the total area covered increased by 18%. The spring DFO RV trawl survey covers most of the stock so survey trends are thought to broadly reflect stock trends.

Spawning is spatially widespread in 3Ps, occurring close to shore as well as on Burgeo Bank, St. Pierre Bank, and in the Halibut Channel. Timing of spawning is variable and extremely protracted, with spawning fish present from March until August in Placentia Bay. Detailed examination of fish collected from Halibut Channel (southern portion of 3Ps) in March and April of 2015 and 2016 suggested that spawning in this area began in April. It was also noted for these fish that females initially categorized as spent were in fact likely skipping spawning, a phenomenon that may have influenced previous estimates of spawning time.

Maturation in female cod was estimated by cohort. The proportion of female cod maturing at ages 4-6 is higher for all cohorts subsequent to the 1985 cohort. The reasons for the change toward earlier age at maturity are not fully understood but may have a genetic component that is partly a response to high levels of mortality including fishing. Males generally mature about one year younger than females but show a similar trend over time.

Growth, calculated from length-at-age in research trawl survey samples, has varied over time. For cod older than age 3 there was a general decline in length-at-age from the early 1980s to the mid-1990s. For most ages there was an increase in length-at-age from the mid-1990s through the mid-2000s, followed by a period of lower length-at-age in recent years. Length-at-age during 2013-16 was among the lowest in the time series.

Condition (or condition factor) is a measure of fish weight relative to length and is considered a proxy for energy reserves. Comparison of post-1992 condition with that observed during 1985-92 is difficult because survey timing has changed. Condition varies seasonally and tends to decline during winter and early spring. There were signs of improved fish condition during 2008-13, but condition values for 2014-16 subsequently declined and are among the lowest in the time series. Similarly, estimates of condition from sentinel sampling in recent years are below the time-series average.

ASSESSMENT

Resource Status

Sources of Information

A cohort model (SURBA) based on abundance indices from Canadian RV trawl surveys (1972-2016) is used to infer overall stock trends (Cadigan 2010). This model can only use a single index of stock abundance. Although additional sources of information are presented (see "Other Data Sources" below), the RV survey data was selected as the model input data because it is collected with a standardized design over most of the stock area and is thought to best reflect overall trends in the stock.

Research Vessel Surveys

Canadian DFO RV bottom **trawl surveys** have been conducted in 3Ps since 1972, however, surveys from 1972-82 had poor coverage. The surveyed area was increased by 18% by the addition of strata closer to shore in 1994 and 1997. The survey was not completed in 2006.

Survey indices based on index strata <550 m (<300 ftm) are presented for the expanded DFO survey area (inshore and offshore; denoted "All index strata" in Figs. 3 and 4) as well as for the offshore strata ("Offshore index strata" in figures). The DFO RV survey covers most of the stock distribution, and survey trends are considered to broadly reflect stock trends. Any near-shore aggregations in April would not be measured by the DFO RV survey. The majority of the area shoreward of the DFO RV survey lies within inner and western Placentia Bay. There is no recent evidence that a large fraction of the stock is shoreward of the DFO RV survey in April.

The **biomass index** from the offshore strata is variable but exhibits a downward trend from the mid-1980s to the early 1990s (Fig. 3). Values for most of the post-moratorium period up to 2004 were higher than those of the early 1990s, but not as high as those of the 1980s. Biomass estimates in recent years have generally been low, with seven of the last ten years being below the 1997-2016 average. Survey catches in 2016 were generally low, except for one large survey catch on Burgeo Bank. Survey biomass from the expanded index ("All index strata") shows similar trends to the offshore-only index.

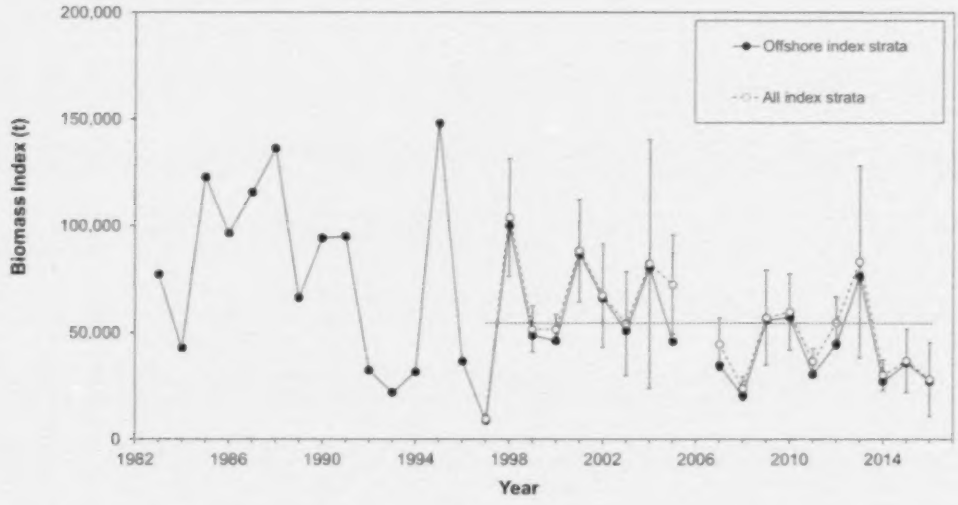

Figure 3: RV survey biomass indices (t) (error bars are ± one standard deviation for combined survey index–dashed line is the time series average of the combined survey index).

The offshore DFO RV abundance index is variable, but values during the 1990s were generally lower than those from the 1980s (Fig. 4). Abundance was low during the 2000s but has increased somewhat in recent years with six of the last nine years being at or above average. In particular, the 2013 estimate was very high but characterized by a high degree of uncertainty.

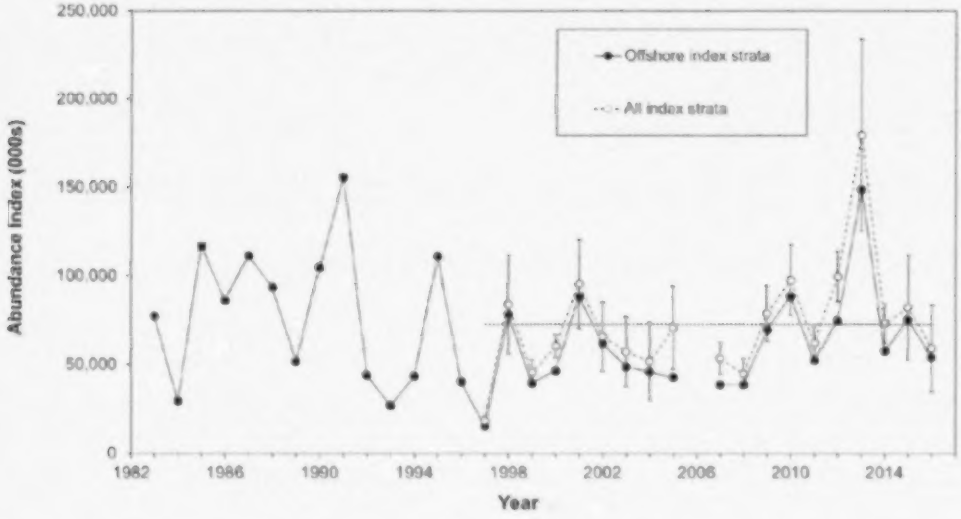

Figure 4: Research vessel survey abundance indices (error bars are ± one standard deviation for combined survey, dashed line is average of combined survey index).

Age Composition

Catches during the 2016 RV survey consisted mainly of cod aged 2-6 (90% of abundance index). Indications are that the 2011 (age 5 in 2016) and 2012 (age 4 in 2016) year classes are strong. The degree to which these two year-classes will contribute to future fisheries is as yet uncertain. The abundance of cod older than age 6 is low.

Cohort Analysis Reference Points

The Limit Reference Point (LRP) for this stock is $B_{Recovery}$, the lowest observed spawning stock biomass (SSB) from which there has been a sustained recovery. The 1994 value of SSB has been identified as the LRP. The Upper Stock Reference (USR) has been defined as two times the LRP. Removal reference points have not been identified for this stock.

Spawning Biomass

Cohort analyses of the RV data indicated that SSB declined by 58% over 2004-09 (Fig. 5). Median SSB was estimated to be below the LRP in 2009. SSB increased considerably over 2009-12 but has since declined. Although the stock is currently estimated to be in the Cautious Zone (18% above B_{lim}) as defined by the DFO Precautionary Approach (PA) Framework, the probability that the stock is in the critical zone is 0.22, which is a concern. There are further concerns that the current estimate of SSB could be biased as the model has overestimated SSB in recent years (see 'Sources of Uncertainty' section). Very low numbers of older (ages 6+) fish in the population combined with the presence of the strong 2011 and 2012 year classes resulted in nearly half (46%) of the 2016 SSB being made up of 4-5 year old fish. This is an enormous reliance on young spawners and may be a concern given that younger fish produce fewer and smaller eggs/larvae that may have reduced survival. Young fish also spawn over a narrower

time frame which decreases the probability of overlap between larval emergence and peak plankton abundance and can result in reduced survival.

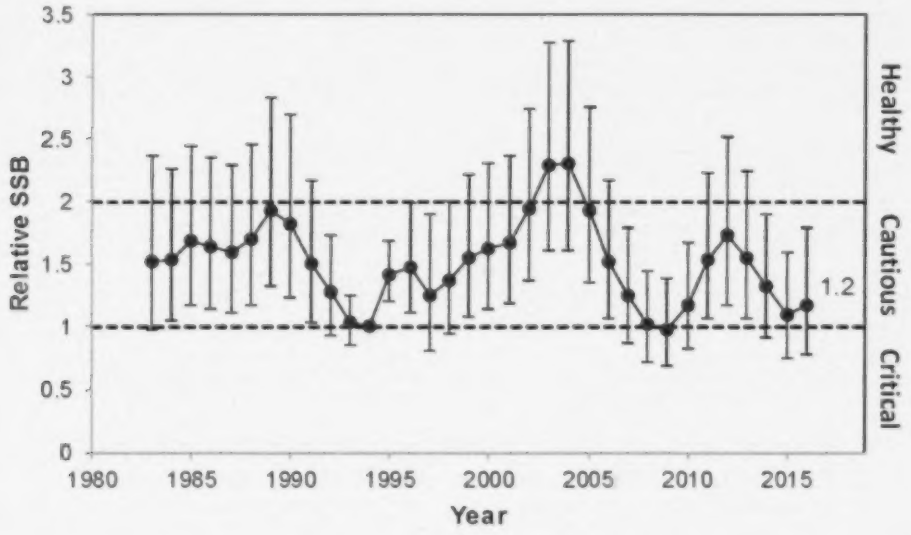

Figure 5: Cohort analysis estimates of SSB, relative to the 1994 value (median estimate with 95% confidence interval). The lower dashed line at one (reference level) represents the SSB Limit Reference Point and the upper horizontal dashed line at two represents the Upper Stock Reference (i.e., 2 x LRP). These reference points represent the boundaries between the zones of DFO's precautionary approach framework, as indicated on the right axis. Text label indicates the current SSB relative to the LRP.

Mortality Rates

Total mortality rates reflect mortality due to all causes, including fishing. Estimated total mortality from the cohort model (Fig. 6) for ages 5-10 has generally been increasing since 1997 and the 2015 estimate is the highest in the time series. Over 2013-15, the total mortality rate averaged 0.73 (equivalent to 52% per year). This is very high considering that landings have been about half of the TACs over this time period. The current truncated age structure indicates that fish in this population are not surviving to older ages and the extent to which this might be related to recent low nutritional condition and/or early age at first maturity is not certain.

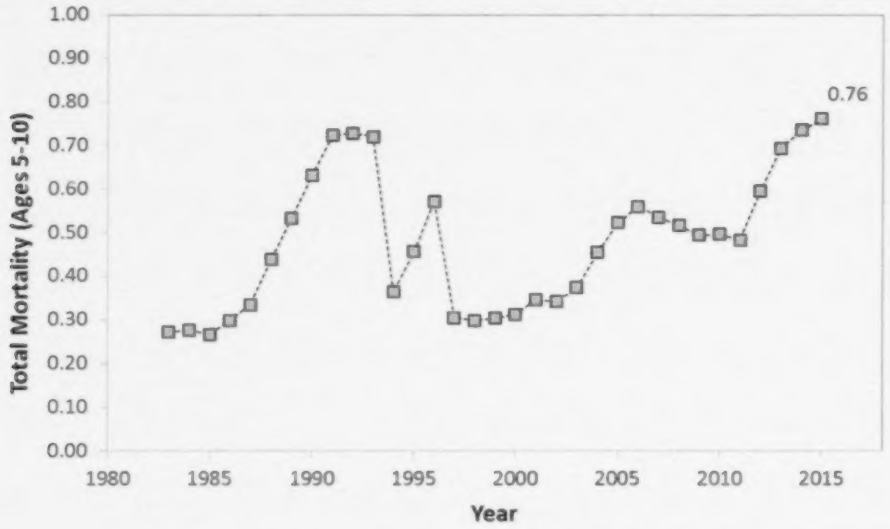

Figure 6: Cohort analysis estimates of population weighted average annual mortality (ages 5-10). Text label indicates the estimated total mortality for 2015.

Recruitment

Recruitment (Fig. 7) has improved over the last decade with most cohorts at or above the time series (1983-2014) average. Indications are that the 2011 and 2012 cohorts are among the strongest in the time series. However, even these strong cohorts are expected to decline rapidly in coming years if total mortality rates remain at recent high levels.

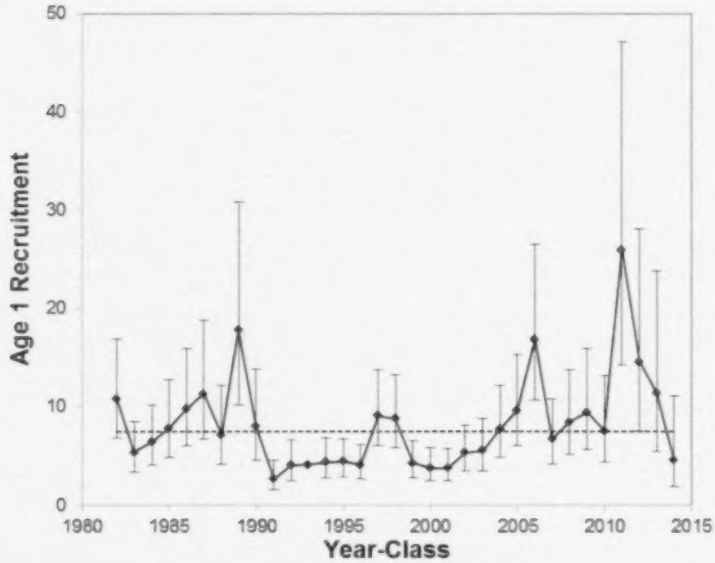

Figure 7: Estimated relative year-class strength from cohort model (median estimate with 95% confidence intervals). The dashed horizontal line is the time-series median.

Projection

The consistent direction in retrospective patterns in SURBA model estimates among recent assessments, and the unavailability of recent estimates of commercial fish weights-at-age (see 'Sources of Uncertainty' section) led to the decision to not project the current assessment results forward. In general, however, it is noted that biomass is likely to decline sharply in the coming years if the current high mortality rate persists.

Harvest Control Rule

The Conservation Plan and Rebuilding Strategy adopted by Canada to guide management decisions includes a Harvest Control Rule for calculating the TAC based on recent stock trends and current stock status. The rule calculates a proposed TAC for the coming year by adjusting the current year TAC based on the trend in SSB.

The value calculated by the HCR has been adopted as the TAC for this stock for the last two years. However, catches of approximately half these values have not promoted recovery of the stock toward the healthy zone. It was therefore not considered prudent to provide management advice for 2017/18 based on the HCR.

Given the downward trajectory of the stock in recent years, coupled with the current close proximity of the stock to the LRP, it is recommended that catch be reduced below recent levels.

Other Data Sources

Other sources of information were considered in the assessment to provide perspectives on stock status in addition to the DFO survey indices. These sources of information include data from the Sentinel survey (1995-2015), exploitation (harvest) rates estimated from tagging experiments in Placentia Bay (and more recently Fortune Bay), and results of a telephone survey of inshore Canadian fish harvesters. Updated logbook data for vessels less than 35 ft and vessels greater than 35 ft were not available for the current assessment. Any differences in trends between these additional data sources and the DFO survey are difficult to reconcile but attributed to differences in survey/project design, seasonal changes in stock distribution, differing selectivity of various gear types, or the degree to which the various data sources track only certain subareas/ components versus the entire distribution of the stock.

Sentinel survey

Fixed gear sentinel surveys have been conducted at sites along the south coast of Newfoundland from St. Bride's to Burgeo from 1995 through 2016. Gillnet results come mostly from sites in Placentia Bay whereas line-trawl results come mostly from sites west of the Burin Peninsula. The sentinel survey for 2016 is still ongoing; hence, the data for 2016 are incomplete and were not included in the modeling reported below.

The sentinel survey data were standardized to remove site and seasonal effects to produce annual indices of the total and age-specific catch rates (Fig. 8).

The standardized total annual catch rate for gillnets was highest from 1995-97, but progressively lower in 1998 and 1999, and remained quite low from 2000 to 2015 (Fig. 8, upper panel). The line-trawl catch rates were high in 1995 with a steady decline to 1999, but were subsequently fairly constant through 2009 (Fig. 8, lower panel). More recent (2013-15) values are the lowest in the time-series.

The standardized age-specific catch rates for sentinel gillnets and line-trawls show similar trends with the relatively strong 1989 and 1990 year-classes being replaced by subsequent weaker year-classes resulting in an overall decline in catch rates. Although the magnitude of the

sentinel catch rates has been generally constant for more than a decade, the 1997 and 1998 year-classes were consistently evident in both age disaggregated sentinel indices. In addition, the 2004 year-class appears to be well-represented only within line-trawl results. The relative strength of more recent year-classes in the sentinel results is less clear, but generally indicates that they are relatively weak. Comparison of sentinel catch rates and the RV index at times show inconsistent age compositions; these differences are not fully understood. As an example, the 2006 year-class ranks above average in the RV survey, but does not appear particularly strong in either sentinel index even though fish in this year-class are now available to these gears. The 2011 and 2012 year classes, which appear strong in the survey, were not yet of age to be fully selected by either of the gears in the 2015 sentinel survey.

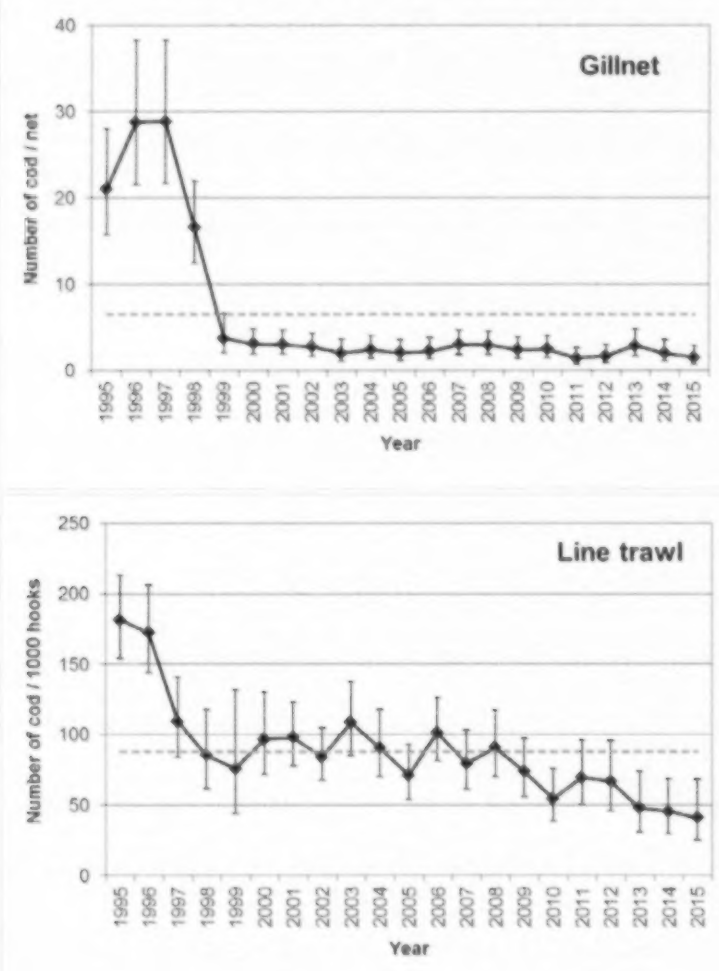

Figure 8: Standardized sentinel catch rates for gillnets (upper panel) and line-trawls (lower panel). Error bars are 95% confidence intervals; dashed lines represent the time-series average.

Tagging

The geographical coverage of tagging since 2007 has been limited to inshore areas, which causes some uncertainty as to how results relate to the stock as a whole. The number of cod and areas where tagging was conducted was expanded from only 3Psc (Placentia Bay) to

include 3Psb (Fortune Bay) in 2012-15 and 3Psa in 2013. Although exploitation rates based on tagging of cod in these inshore areas may not be applicable to other areas, or to the stock as a whole, these inshore regions account for a significant portion (~ 50%) of the overall annual landings from the stock.

Exploitation rates for 2015 were obtained. These incorporated annual estimates of tag reporting rates (~ 68% during 2015) based on high-reward tagging and a range of assumed values for the annual rate of natural mortality (M=0.2 or 0.4). At M=0.4, in 2015, the harvest rates ranged from 9% to 20% (F=0.09 to 0.23) among cod 50-85 cm at release tagged in Placentia Bay and Fortune Bay. These values would be approximately double if the entire quota had been taken as most of the unharvested TAC was available to the inshore sector. Recent tagging suggests exploitation of 3Ps cod in neighbouring stock areas (Divs. 3KL) is minimal and not a major issue for management. No new data are available to investigate mixing in the western portion of the stock area (3Psa/d). Overall, post-moratorium inshore tagging studies have generally revealed extensive movement of cod between Placentia Bay (3Psc) and Fortune Bay (3Psb), but limited movement from inshore to offshore. In contrast, many cod tagged offshore in Halibut Channel (3Psh) have shown extensive seasonal movement shoreward, particularly into Placentia Bay during summer.

FFAW Telephone Survey

Canadian fixed-gear fish harvesters' perspectives on the 2015 fishery were compiled based on the results of the telephone survey conducted by the Fish, Food and Allied Workers Union (FFAW). Results are based on the responses of 87 active harvesters. Respondents to the survey generally reported fish abundance during the 2015 season as average in Placentia Bay and west of the Burin Peninsula. Above average abundance was reported for St. Pierre Bank. It is noted that these results do not agree with results of the RV survey, nor the opinions expressed by most inshore harvesters present at the meeting.

The abundance of baitfish, specifically capelin and squid, was reported as being at a low level and decreasing throughout 3Ps. There was a range of responses regarding herring abundance in Placentia Bay. Approximately half of the harvesters fishing in the St. Pierre Bank region reported a good abundance of sandlance. Few harvesters reported seeing baitfish in cod stomachs. Reports of shellfish, including shrimp, and toad, rock, green and snow crabs were more common.

Sources of Uncertainty

Although the RV survey of Subdivision 3Ps includes coverage of 45 index strata, the majority of the survey indices for cod are typically attributed primarily to only a small number of those strata. In some years the high estimates in some of these strata are a result of a single large survey tow. For example, in three of the last four years, a large survey tow on Burgeo Bank has had a major influence on survey indices (e.g. 60% of the biomass index in 2016 resulted from a single survey tow in stratum 309). The presence of single large survey tows results in increased uncertainty in the survey data.

Survey indices are at times influenced by "year-effects", an atypical survey result that can be caused by a number of factors (e.g., environmental conditions, movement, degree of aggregation, etc.) which may be unrelated to absolute stock size. There are strong indications that the 2013 survey may have been influenced by a year effect that resulted in a large spike in the survey indices for that year. The 2013 RV survey estimated that the abundance of multiple cohorts increased compared to observations of these same cohorts at one age younger in 2012. Since the number of fish in a cohort cannot increase as it ages (without immigration), such

results are usually considered clear evidence for a year effect. Year effects in the survey data have the potential to mask trends in the data and contribute to retrospective patterns.

Recent assessments of 3Ps cod have been subject to retrospective revisions of estimates from previous years with the addition of a new year's survey data. For example, in the 2015 assessment the SSB for 2015 was estimated to be at 1.4 times the level of the LRP. In the current assessment, however, the 2015 SSB has been retrospectively revised downward to less than 1.2 times the level of the LRP. This is the third assessment in a row where the terminal year estimate of SSB has been revised downwards compared to the previous assessment. Likewise upward retrospective revisions of mortality have occurred over the same period. Retrospective revisions are not uncommon in cohort models, which use annual information to predict the abundance of multiple cohorts. However, strong retrospective patterns in the same direction over multiple years could suggest an issue with input data and/or model formulation. Concern was expressed over the magnitude and direction of the retrospective in recent years.

This assessment uses fish weights-at-age from the commercial fishery along with proportions mature-at-age to convert numbers-at-age into spawning stock biomass. However, ageing of otoliths from the 2015 and 2016 3Ps commercial fisheries was not completed prior to the current assessment due to age-reading obligations related to other high-priority assessment/framework meetings. Therefore the average weights-at-age for the three previous years (2012-14) were used. RV survey data suggest that current fish weights are lower than previous years and hence the use of weights from previous years could result in current SSB being overestimated.

Burgeo Bank is a known seasonal mixing area for cod from 3Ps and those from the Northern Gulf of St. Lawrence. The DFO RV survey was moved to April in 1993 to minimize the impact of migratory Northern Gulf fish on the assessment of 3Ps cod. However, at least one published study suggests that a non-trivial portion of fish in the Burgeo Bank area in April is of Northern Gulf origin (Méthot et al. 2005). The potential presence of non-3Ps fish in this area at the time of the survey combined with the fact that a large portion of the survey indices have come from the Burgeo Bank area in recent years suggests the potential for overestimation of survey results.

The level of total removals is uncertain. It is likely that landings have been biased both upwards (e.g., due to misreporting of catch by area and/or species) and downwards (e.g., due to discarding). In addition, commercial catch accounting procedures pre- and post-moratorium are radically different, with current measures likely to provide improved estimates of removals. Estimates of recreational fishery landings have not been available since 2006. In assessing stock status, it would be useful to better understand the accuracy of total removals. Given these uncertainties and the variability in the reliability of removals estimates, the decision was previously made to assess this stock based on a cohort model that incorporates only RV catch information (i.e., no commercial catch data). Assessment models do exist that are capable of handling uncertainty in the catch estimates but a full evaluation of these or any other model formulations would require a framework meeting.

The relative efficiency of the survey trawl at capturing different age groups is uncertain. Differing patterns of catchability were explored in a recent assessment and yielded a similar outcome in terms of current status relative to the LRP. If the catchabilities differ from the assumed values, stock dynamics may differ from the results presented above.

CONCLUSIONS AND ADVICE

- Although the stock is currently estimated to be in the Cautious Zone (18% above B_{lim}) as defined by the DFO Precautionary Approach (PA) Framework; the probability that the stock is in the critical zone is 0.22, which is a concern.

- There are further concerns that the current estimate of spawning stock biomass (SSB) could be biased as the model has overestimated SSB in recent years.
- The SSB has declined since 2012 and there are few older (ages 6+) fish in the population.
- The strong 2011 cohort is now of age to recruit to the fishery. The subsequent cohorts are lower but near the time-series average.
- Estimated total mortality has been increasing and the 2015 value is the time-series maximum. Over 2013-15, total mortality averaged 0.73 (52% per year). This is very high considering that landings have been about half of the TACs over this time period.
- Projection of the stock to 2019 was not conducted. If the current high mortality rate persists, it will result in a sharp decline in biomass in the coming years.
- Recent trends in mean size and weight-at-age, fish condition and age-at-maturity are at or near their lowest observed levels. This is consistent with broader ecosystem trends (e.g. warming temperatures, changes in community structure and cod diet composition) which also suggest some aspects of cod productivity may be impaired.
- Catches of approximately half the TAC generated from the HCR in recent years have not promoted recovery of the stock toward the healthy zone. It was therefore not considered prudent to provide management advice based on the HCR.
- Given the downward trajectory of the stock in recent years, coupled with the current close proximity of the stock to the LRP, it is recommended that catch be reduced below recent levels.

OTHER CONSIDERATIONS

Management Considerations

The assessment of 3Ps cod is based on a cohort model that utilizes data from the DFO spring RV survey. Other data sources are typically examined during the course of the assessment meeting but have previously been eliminated as potential inputs for modeling population dynamics due to questions regarding reliability (e.g., catch), concerns related to limited spatial coverage (logbook data, sentinel data, tagging data), and/or the inability to incorporate more than one data source into the current model formulation. However, given recent concerns regarding the retrospective pattern in SURBA model estimates, a framework meeting to fully re-evaluate all data sources and modelling options is recommended.

A seasonal closure of the entire 3Ps stock area (typically March to mid-May) occurs annually and is intended to minimize fishing on spawning aggregations. Some harvesters have suggested that the time of spawning has been delayed in recent years and that the timing of the closure may no longer be appropriate. Fishing was permitted in March 2014 and 2015 to provide those harvesters with increased flexibility in accessing the resource. In 2015 and 2016, samples collected from the Halibut Channel area (Southern 3Ps) by industry (March) and from the DFO multispecies survey (April) indicated that spawning in this area began in April. No spawning was observed in March but egg sizes suggested that at least some fish were nearing spawning at the time of capture. The original recommendation for the 3Ps spawning closure came with the suggestion that spawning in this stock occurs during April-June but with the acknowledgement that "spawning ground behavior typically begins in March" (FRCC 2001). Hence, the recommended (and subsequently adopted) closure time of March 1-June 30 was presumably intended to protect not only spawning but also pre-spawning aggregations. If the objective of the 3Ps spawning closure is still to protect spawning and pre-spawning

aggregations, then the starting date of the closure is likely still appropriate. It should be noted, however, that the current closure end date of mid-May almost certainly does not protect the full spawning period for this stock.

SOURCES OF INFORMATION

This Science Advisory Report is from the October 17-19, 2016 Assessment of Northwest Atlantic Fisheries Organization (NAFO) Subdivision 3Ps Atlantic Cod. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

Cadigan, N. 2010. Trends in Northwest Atlantic Fisheries Organization (NAFO) Subdivision 3Ps Cod (*Gadus morhua*) stock size based on a separable total mortality model and the Fisheries and Oceans Canada Research Vessel survey index. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/015. iv + 43 p.

FRCC. 2001. Conservation requirements for groundfish stocks in sub-areas 0, 2 + 3. Ottawa, Canada. 39 p.

Méthot, R., M. Castonguay, Y. Lambert, C. Audet and S. Campana. 2005. Spatio-temporal Distribution of Spawning and Stock Mixing of Atlantic Cod from the Northern Gulf of St. Lawrence and Southern Newfoundland Stocks on Burgeo Bank as Revealed by Maturity and Trace Elements of Otoliths. J. Northw. Atl. Fish. Sci. 36: 1–12

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